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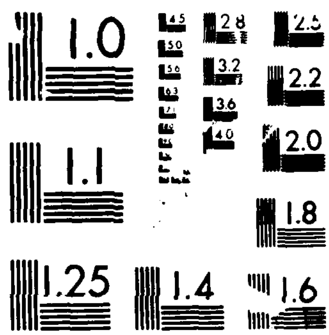

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U.S. AIR FORCE APPLICATION OF A U.S. ARMY TRANSPORTATION CAPABILITY ASSESSMENT METHODOLOGY

THESIS

Nancy L. Needham
Captain, USAF

AFIT/GLM/LSMA/87S-50

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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U.S. AIR FORCE APPLICATION OF A U.S. ARMY TRANSPORTATION CAPABILITY ASSESSMENT METHODOLOGY

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

Nancy L. Needham, B.G.S.

Captain, USAF

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I claim this thesis to be an outward sign of the love of Jesus Christ, our Lord and Savior, and the inspiration of the Holy Spirit. God, our Father, used many holy men and women as His instruments to develop this thesis and I would like to acknowledge their willing friendship and support.

This thesis was born in the writings and hard work of Joshua Davis, David Dorfman, and many members of the entire MTMC Transportation Engineering Agency Staff. They developed the methodology discussed in this thesis and provided endless support for my needs. Their work shows great insight into the needs of transportation planning.

I proudly salute the Best Aerial Port in the Air Force for 1986, the 435th at Rhein Main Air Base, for their professionalism, hard work, and comraderie. The men and women of the 435th touched my life and made this thesis a cornerstone for future improvements in transportation planning.

In addition, Col Richard Meyer, Mr. Tom Spade, and Maj Kent Gourdin provided the encouragement and direction needed to make this thesis possible.

I dedicate this work to my friend and shepherd, Judy Hoelscher. And to my parents, Tom and Lorene Needham, who raised me with a strong Irish spirit, I shout "Gung Ho"!

— Nancy L. Needham

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Abstract

Currently, no quantitative tool exists which would provide a complete assessment of an Air Force Base's interface with the Defense Transportation System in its specific wartime roles. However, the Army's Transportation Engineering Agency (TEA) has developed and is utilizing a methodology for assessing the surface (rail and motor) capability of Department of Defense (DOD) transportation systems. While the methodology has been used to evaluate many DOD installations and several Air Force bases, the results exclude air transportation capability.

This thesis expands the Army's methodology as the basis for a more complete Air Force transportation capability assessment tool. The enhanced version is validated by application of TEA's measurement principles and models to the inbound air transportation functions of an Air Force base. The specific objective for development of the new capability evaluation tool was to quantify a base's ability to receive cargo on its flight line and to move the cargo through processing facilities and off the base at various peacetime and wartime activity levels.

The assessment technique developed in this thesis was applied to a peak work load scenario. The analysis revealed forklift and storage shortfalls, as well as, capability excess in truck loading positions. Thus, this

analysis demonstrated that the Army's methodology is sufficiently flexible to measure the air inbound cargo flow of an Air Force base.

In summary, the methodology can model all components of the transportation system and assess the capability of an Air Force base to meet mission requirements of a given scenario within the limits of available equipment and facilities. The basic concept learned from using this methodology is a new awareness of the intricacies of a base's transportation infrastructure. This new level of awareness can lead to better management of critical base level resources, as well as improved combat capability for U.S. military forces. In addition, this assessment technique is an aid to testing the feasibility of war plans. Base level transportation planners now have a tool to better evaluate contingency scenarios as they are tasked and planners at higher headquarters can evaluate the total transportation feasibility of plans before they are finalized.

U.S. AIR FORCE APPLICATION OF A U.S. ARMY TRANSPORTATION CAPABILITY ASSESSMENT METHODOLOGY

I. Introduction

Overview

At a moment's notice, the United States military must be prepared to support national objectives in any place around the world (23:2A.45). The degree of the military's preparedness is often termed as "readiness," which is ultimately translated to combat capability (29:2; 23:2A.47). To measure whether military forces have sufficient capability, many mathematical models have been developed by the Services (4:8; 23:2A.58). The systems theory approach is utilized in these models to ensure they are complete, reliable, and valuable (26:6; 30:134). This approach is most appropriate because it recognizes the interrelatedness of the various systems of U.S. military capability, as well as their contribution to the overall effectiveness of the larger system of defense (30:44).

Within the defense system is a key subsystem called logistics. It is the process of getting the right forces, equipment, and supplies to the right place at t e right time (3:1-3; 22:11). The logistics system is comprised of several subsystems including supply, maintenance, and transportation (17:v). These functions, have traditionally been viewed with optimistic assumptions of availability (4:512). However, one function--transportation--has outgrown these assumptions due to increased costs of distribution operations, decreased interoperability between the military and civilian sectors, increased use of automation, increased importance in transportation planning, and increased intermodal trends in industry (19:3). These developments, as well as the recent Packard Commission's recommendation to organize a unified transportation command, show the capability of the transportation function to support the logistics system can no longer be assumed (27:xxi,36). Thus, well-defined procedures for measuring transportation capability are required.

The U.S. Army has developed a methodology to quantify the transportation system of an Army installation utilizing a variety of mathematical models (7:20-21). In addition, the Army's style of analysis provides a basis for evaluating the transportation system capability of an Air Force base and is the framework for this thesis.

General Issue

The Army's Military Traffic Management Command (MTMC) Transportation Engineering Agency (TEA) has developed and is utilizing a methodology for assessing the capability of an Army installation's transportation system (5; 6; 7; 8; 31). While the methodology has been used to evaluate several Air Force bases, the results exclude Air Force-unique transportation systems which require analysis of airlift capacity, operations, loading procedures, and Aerial Port of Embarkation (APOE) reception planning (31; 21:5). However, much independent research has been done in these areas (4:510; 15:2). This thesis expands MTMC's methodology to provide a more complete assessment of the transportation capability of Air Force bases.

Background

In 1976, the Transportation Engineering Agency of MTMC was directed to develop an installation transportation capability assessment tool for U.S. Army installations. The tasking was a result of Exercise REFORGER (Return of Forces to Germany) after-action reports on the transportation capability of U.S. Army Installations. When the methodology was first developed, it was only applied to Army installations in the continental United States (CONUS) which were involved in REFORGER. However, as the methodology proved to have high internal validity, it was applied to other Army installations, Army ammunition plants, and many Defense Logistics Agency facilities (8).

Within Army channels, information from this transportation capability assessment tool is incorporated into an annual report, the CONUS Military Installation Material Outloading and Receiving Capability Report. This report is used by MTMC war planners to analyze the outloading and receiving capability of installations during peacetime, mobilization, and deployment (12:1). Currently, the Transportation Engineering Agency is revising the methodology to survey the transportation capability of sixty overseas Army installations at the request of Headquarters European Command (8).

Since 1984, transportation officials of the Headquarters U.S. Air Force Directorate of Transportation (HQ USAF/LET) have initiated requests for application of the TEA methodology to the surface transportation (rail and motor) capabilities of several Air Force bases, including Dover Air Force Base (AFB), Delaware; Charleston AFB, South Carolina; Seymour-Johnson AFB, North Carolina; McChord AFB, Washington; and Travis AFB, California. The TEA transportation engineers conducting the studies noted in their reports that the subsystems of transportation related to airlift operations were beyond the scope of the study (21:5). Yet, transportation managers at HQ USAF/LET believe the assessment of an Air Force base's transportation capability should be expanded to include a focus on air transportation capability. Further, they believe the Air Force needs to develop the specific criteria for expanding MTMC's assessment tool (31). As a first step toward this end, an overview of the current TEA methodology will follow.

The purpose of TEA's method of analysis is to evaluate an installation's capability to move cargo into its physical boundaries, within its physical boundaries, and off the installation by rail and truck at a peak wartime activity level (6:1). The regimen consists of five steps:

1. define the mobilization mission and operational procedures of the installation;
2. describe the fixed transportation facilities and mobile transportation equipment, which defines the transportation system;
3. define the mobilization transportation requirements;
4. determine the capability of the transportation system; and
5. draw conclusions and make any recommendations that may be necessary to upgrade the system's capability to meet or exceed mobilization requirements [6:2].

Within each step, procedures are specified to depict data collected as flow diagrams for all components of the transportation system and as tables comparing requirements to capability. If the system's capability doesn't meet mobilization requirements, recommendations are made to correct the deficiency (6:2).

MTMC's methodology is a significant improvement over past methods of determining transportation capability (7:21). The Defense Transportation Journal sums up the Transportation Engineering Agency's contribution:

In the past, planning focused primarily on the capability to move material off the installation, not into it or within it. However, an installation must be looked at as a complete system, which can only be as strong as its weakest subsystem. With this new method applied to all military installations, our readiness to respond to mobilization would be far more secure [7:21].

Problem Statement

Currently, no quantitative tool exists which would provide a complete assessment of an Air Force base's interface with the Defense Transportation System in its specific wartime roles. However, both MTMC TEA and HQ USAF/LET agree that research in this area will enhance the readiness of U.S. military forces (5; 28).

Research Objective

This thesis expands TEA's methodology as the basis for a more complete Air Force transportation capability assessment tool. The enhanced version is validated by application of TEA's measurement principles and models to the inbound air transportation functions of an Air Force base. The objective of the new evaluation system is to quantify a base's ability to receive cargo on its flight line and to move the cargo through processing facilities and off the base at various peacetime and wartime activity levels.

Investigative Questions

There are four central investigative questions relevant to this thesis.

1. What is transportation capability?

2. What are the principles involved in measuring transportation capability?

3. What information has been gained as a result of applying the TEA style of analysis to DOD installations?

4. What is an effective technique for measuring air transportation capability?

Chapter III will describe the research techniques utilized to answer these questions.

Scope and Limitations

Although transportation functional responsibilities in the Air Force include maintenance and management of vehicles and movement of cargo and passengers, this thesis only investigates cargo movement. Specifically, the flow of inbound cargo is measured as it is offloaded from aircraft and moved from the flight line to the processing facilities and off the base.

Validation of the analysis techniques used were developed from data collected on only one Air Force base, with consideration given to general application of the finished product to all or nearly all Air Force bases.

Results were restricted by availability of data and limited research in the area of base transportation capability.

Assumptions

The capability assessment technique developed in this thesis is based on the assumption that the mathematical models and principles utilized in MTMC's methodology are valid and based on proper theoretical constructs. Further, the analysis and conclusions of this investigation are based on the assumption that the application of TEA's methodology in this thesis is correct. A third assumption is that the data gathered on inbound cargo flow and procedures of aircraft offloading and cargo processing are applicable to, and respective of, the cargo flow on all or most Air Force bases and that the data gathered are accurate. This thesis is also based on the premise that aircraft offload capability impacts the capability of an air terminal processing facility.

Definitions

The following definitions are provided to enhance understanding of this cross-Service application of research methodology:

1. MTMC Transportation Engineering Agency--an activity of the Army's Military Traffic Management Command which performs analyses of transportation systems (i.e., installation outload studies), provides transportability

criteria and guidance to the Department of Defense (DOD), and furnishes traffic and transportation engineering services for the DOD (1:30; 2:31).

2. Capability--a measure of a system's ability to achieve its mission objective given specific performance criteria (25:1-3).

3. Transportation System--the integrated and coordinated activities of personnel, equipment, and facilities necessary to sustain the systematic movement of material (11:716).

4. Transportation planning--the process of determining which transportation actions or capabilities are needed to accomplish a mission (11:523).

5. Mobilization--the process by which U.S. military forces are brought to a state of readiness for war or other national emergency including assembly and organization of personnel, supplies, and weapons systems (11:455).

Summary

This chapter has described the background, research objective, investigative questions, scope and limitations, assumptions, and key terminology relevant to this thesis effort. Next, Chapter II will review the literature describing transportation system capability assessment and Chapter III will present the methodology utilized to meet the thesis objective.

II. Literature Review

Overview

This chapter presents a discussion and synthesis of three approaches to evaluate transportation system capability. The first two approaches--transportation system analysis and transportation engineering--provide a broad theoretical framework for analyzing capability. The third approach, the MTMC methodology, is a practical application of the principles espoused by the first two. From each viewpoint, this chapter develops the concepts of a transportation system and its capability. Then, a set of mathematical techniques for measuring capability are presented as a framework for analyzing the transportation capacity of Air Force bases. Finally, the chapter concludes with a discussion of the results of some of MTMC's earlier studies of Department of Defense (DOD) installations.

Definition of a Transportation System

Fundamentals of Transportation Systems Analysis by Marvin L. Manheim advocates viewing transportation as a single, multimodal system within its environment (24:11). Manheim identifies three basic variables for the purpose of analysis: the transportation system, the activity system, and the pattern of flows. The flows include origins, destinations, routes, and volumes of goods and people moving through the system (24:12-13). The entire transportation system is composed of many components linked together as sets of subsystems. These subsystems are visualized as a network of facilities for the activities of movement or transfer. Analysis of the flows of these subsystems provides an understanding of their behavior and a means of predicting the effects of internal and external changes (24:164-173). This parallels Schoderbeck's discussion of the systems analysis approach where he defines a system as:

> . . . a set of objects together with relationships between the objects and between their attributes connected or related to each other and to their environment in such a manner as to form an entirety or whole [30:12].

Thus, Manheim's approach is a descriptive, graphical method of defining a transportation system and the relationships between its subsystems.

A second approach to defining a transportation system is found in <u>An Introduction to Transportation Engineering</u> by William Hay. According to Hay, a transportation system model includes two primary components: the physical elements of the system and the environmental or regional elements. Physical elements include vehicles, terminals, people, and activities. The environmental elements consist of factors such as location and climate (18:541). In addition, Hay concurs with Manheim's approach in developing a model of a transportation system that can be presented graphically and mathematically to show the capacity of various factors and their relative relationships (18:541).

A third approach combines the descriptive, graphical, and mathematical approaches of Manheim and Hay. It was developed by C. Joshua Davis of the Army's Transportation Engineering Agency. Davis states that the first step in analyzing a transportation system is to describe all components of the transportation system. He specifies that the task of defining the system is developed by identifying a base's "mobilization response" or wartime tasking and specifying all aspects of its impact through a description of operational procedures. In a recent article, Davis advocated gathering this information by analyzing the flows of the transportation "production" process from receiving resources vital to the tasking, to storage of the resources, to the actual sequence of events in production, to storage of the finished product and, finally, to the methods for delivering the finished product when and where needed (7:21).

In fully defining the transportation system, Davis incorporates a detailed description of the facilities with the amount of equipment supporting the mission and operations. He defines facilities as railroad tracks, roads, and loading/unloading facilities. Equipment assets are rail and motor vehicles, materials handling equipment, and portable railcar loading/unloading ramps (6:3-4).

A concensus of each approach is that a transportation system consists of equipment, facilities, people, and activities operating in an environment and working toward a specific goal or mission.

Definition of Transportation Capability

Manheim defines capability as a level of service, that is, the maximum number of items per unit of time that can be processed through the component of a subsystem (24:268). Hay's text also discusses capability in terms of a level of service required to meet a volume of demand. He says the specific characteristics of a transportation system that provide service for a volume of demand include: capacity, speed, accessibility, flexibility, and frequency. The capability of a transportation system according to Hay is a function of vehicle capability, vehicle speed, and route capability; that is, the number of vehicles that can operate on a roadway at one time (18:265-266).

Davis uses a more detailed approach. In the third phase of his methodology, Davis states that the analyst determines the capability of the system to meet planned requirements by sorting through known constraints on, and maximum operating potential of, equipment, facilities, and people. Material flow diagrams and work flow capacity tables are built to assess maximum flow capabilities for the various transportation functions, such as passenger and freight operations. According to Davis, evaluation of these diagrams reveals subsystems that appear to be weak in supporting mobilization requirements (7:21).

Davis' concept of capability is based on an analysis of each of four major subsystems of a transportation system--(1) loading and unloading facilities, (2) rail network and railcars, (3) truck and tractor fleet, and (4) equipment. Subsystems are evaluated individually and collectively; then, requirements are compared to capability. He concludes that:

> . . . each transportation requirement will usually require the services of at least two subsystems. . . [thus,] the subsystem with the least capability to meet a particular requirement defines the capability of the overall transportation system to meet that demand [6:7].

A consensus of these three authors--Manheim, Hay, and Davis--shows that transportation capability is the ability of a transport system to meet its volume of demand. Further, the goal of transportation systems analysis is to quantify the behavior of vehicles, people, material, and equipment, and to measure the capability of their interactions and flow through the network of facilities and roadways (24:11,173). This thesis develops this type of consolidated approach by focusing on measurement of capability through analysis of these interactions and flows. To further this task, the next section will present Manheim and Hay's approaches to measurement. It will also discuss the details of Davis' method.

Measurement of Transportation Capability

According to Manheim, measurement of the maximum level of material processed through a subsystem, requires five types of mathematical models: service, resource, demand, equilibrium, and activity shift (24:30-31). The service model calculates the volume of the specific activities within a subsystem. The volume of activities equates to a level of service and the resource model calculates the resources needed to meet that level of service. Next, the demand model represents the planned flow or level of service for freight or passengers as determined by the users. The equilibrium model combines the service levels of the individual subsystems to predict the volumes that will flow between them. Finally, the activity shift model is designed to predict changes within a specific activity in response to a change in flow or level of service requested by a user (24:176).

Hay states that capability is measured by the quantity of freight or number of passengers which can be moved per hour or per day between two points by a given combination of fixed plant and equipment assets (18:538). Initially, sources of traffic requirements are identified and evaluated for their maximum generation potential.

Then, traffic routes, modes, volumes, capacities, vehicle trips, and destination points are determined and compared to required capacity (18:480). He goes on to assert that no fully adequate mathematical model has been developed to permit complete evaluation of a transportation system. Thus, the graphical representation must be broken down through analysis of the relationships between the subsystems. These relationships must be quantified and evaluated against performance criteria and optimization by minimizing cost to achieve maximum capacity for a given level of resources (18:538-539).

Davis' method is a combination of transportation system analysis and the transportation engineering approach and uses five steps of intensive, systematic analysis. It is described in detail here to facilitate understanding of the framework for this thesis.

MTMC TEA Methodology

In October 1984, C. Joshua Davis, a civil engineer of MTMC's Transportation Engineering Agency, presented a paper entitled "Installation Transportation Capability Study Methodology" to the 23rd Army Operations Research Symposium (5). His presentation detailed the five steps of the methodology as outlined in Chapter I.

1. define the mobilization mission and operational procedures of the installation;
2. describe the fixed transportation facilities and mobile transportation equipment, which defines the transportation system;

3. define the mobilization transportation requirements;
4. determine the capability of the transportation system; and
5. draw conclusions and make any recommendations that may be necessary to upgrade the system's capability to meet or exceed mobilization requirements [6:2].

In quantifying these steps, Davis assumes availability of sufficient commercial transportation during mobilization, availability of required personnel, and that a three-shift, twenty-four-hour operation would permit twenty hours of productivity each day (6:7).

Before conducting the actual analysis, Davis' procedure recommends development of tables which divide transportation requirements into specific activities such as: loading, transporting, or unloading. These tables also depict the subsystems utilized by the specific activities. For example, a rail loading activity may require materials handling equipment (MHE), portable ramps, and/or a special loading facility. Lack of access to specialized loading equipment or to a vital facility may reduce the capability of the rail loading activity (6:7).

Step 1. Mission and Operations. This step is accomplished by defining the mobilization mission and operational procedures of the installation. The basis for defining the mission is quantifying and describing the types of cargo flowing through the installation. The operational procedures of the base are described as a flow of materials entering the base; a flow through input storage facilities to one or more production facilities; the flow of finished goods to output storage facilities; and the flow of outputs leaving the base (6:3). According to Davis, the key is to draw a material flow diagram showing three key processes: (1) receiving inputs to the production process, (2) major intraplant movements, and (3) shipment of finished goods (6:3).

Step 2. Facilities and Equipment. This step is accomplished by inventory of on-hand assets (facilities and equipment), review of authorized assets, and expected mobilization assets (wartime assets). According to Davis' abstract, facilities and equipment include production and storage facilities, the rail system, roadways, pipelines, loading/unloading facilities, locomotives, railcars, trucks, tractors, trailers, forklifts, and container handling MHE (6:3-5).

Step 3. Mobilization Transportation Requirements. Definition of transportation requirements is divided into five areas. The first area is the mobilization production schedule (i.e., monthly production rates for the first twenty-four months of mobilization). This schedule is considered the "driving force" for transportation requirements because peak production levels are used to derive the mobilization transportation requirements (6:5).

The second area is receiving requirements. This includes the average number of commercial railcars and trucks per day required to deliver all production inputs during peak mobilization (6:5).

The third area is material requirements. These requirements are first derived from the production schedule. Then they are combined with all probable modes of shipment and typical shipment sizes to express receiving requirements in numbers of railcars and trucks per day (6:5).

The fourth area of system requirements defined is intraplant movement. These requirements are calculated to show the average number of railcar and truckloads per day required to be transported from one point to another to support the mobilization production schedule. They include movement of input materials from storage facilities, movement of in-process materials within production facilities, movement of finished goods from production to storage facilities, and movement of finished goods from storage to transfer loading docks (6:5).

Finally, shipping requirements are calculated to show the mean number of commercial railcars and trucks per day required to ship all production units during peak mobilizations. The mobilization production schedule is combined with palletization and shipment size information to express shipping requirements in numbers of railcars or trucks per day (6:6).

Step 4. Transportation System Capability: Subsystem Analyses. In this step, capability formulas are applied to four transportation subsystems and a final comparison table is built. The subsystems are: (1) loading/unloading facilities, (2) locomotive/track network and railcar fleet, (3) truck/tractor fleet, and (4) materials handling equipment portable ramps (6:8).

Loading/unloading facilities are first analyzed by identifying each building and the transportation activities associated with it. Then, the maximum number of vehicles that can be loaded or unloaded at one time is determined and labeled as CV or total vehicle capacity. Next, the loading and unloading time for each activity is measured and annotated as LT. As stated in the assumptions, the estimated productive time for personnel in each work center, PT, is twenty hours. So, for a facility where only one transportation activity takes place, the formula for CF, facility capability is:

$$CF = \frac{CV \quad X \quad PT}{LT}$$

where

CV = total vehicle capacity

LT = loading/unloading time for the activity

PT = estimated personnel productive time

CF = facility capability (6:8)

If more than one transportation activity takes place at the facility, a facility utilization factor, W_i, for each activity must be calculated from the requirements determined in step three. The requirement (REQ) for each activity is expressed in terms of railcars per day (RCPD) or trucks per day (TPD) and the loading/unloading time needed. The formula is first built as follows:

$$W_i = \frac{REQ_i \times LT_i}{\sum_{i=1}^{n} REQ_i \times LT_i}$$

where

W = facility utilization factor for each activity

REQ = requirement for each activity

LT = loading/unloading time for each activity

i = index number of each activity

n = number of activities (6:9)

The resulting facility utilization factors are then incorporated in the following formula:

$$CF = \sum_{i=1}^{n} \frac{W_i \times CV \times PT}{LT_i} \qquad (6:8)$$

The capability of the locomotive/track network and railcar fleet is analyzed by simulation of expected daily activities. Functions simulated include: (1) coupling/uncoupling railcars to the train, (2) loading/unloading railcars onto specialized transfer cars, (3) setting/ releasing brakes of railcars, (4) transiting from one point of the track network to another, and (5) waiting for railcars to be loaded/unloaded or for another train to clear a track (6:9-10).

Next, a train movement schedule is developed from the simulation to estimate productive time needed from the locomotive and railcar fleets to meet mobilization or wartime requirements. Requirements are compared to expected availability which is based on an inventory of assets on hand and equipment maintenance status history. This prodedure determines capability (6:11).

Capability of the truck and tractor fleet is analyzed based on the estimated productive time needed to meet mobilization requirements. First, total loading/unloading time is estimated by multiplying the daily requirement in trucks per day by the loading/unloading time for each activity. Then, transit times are calculated for intrabase activities. Finally, the expected waiting time that a truck may have to wait for another truck to finish loading or unloading before it can be served is measured. The capability of the fleet is determined when the total required productive time is compared to the expected availability of the truck fleet based on the current inventory and in-commission rate (6:11-12).

The capability of the fourth subsystem, equipment, is also determined by estimating the productive time needed to meet maximum requirements. Analysis is made by comparing total productive time to expected availability of equipment; that is, the inventory of equipment on hand is multiplied by the in-commission rate (6:12). After the capability of the four individual subsystems is calculated, a comparison table is built to identify the "weak link" subsystem--the one with the least capability (6:7,12-13).

Step 5. Conclusions and Recommendations. If a particular subsystem's capability does not meet mobilization or wartime requirements, then alternative courses of action to improve or modify capability are provided. Typical recommendations include facility repairs, construction or deletion, equipment purchase or repair, and removal of excess assets. Each alternative is presented in terms of the amount of increased capability it can provide (6:13).

Examples

To illustrate application of Davis' approach, six studies utilizing his methodology are reviewed next: the May 1983 study of the Iowa Army Ammunition Plant, the October 1984 study of the Defense Construction Supply Center (Columbus, Ohio), the December 1985 study of the Indiana Army Ammunition Plant, the July 1986 study of

Seymour-Johnson AFB, the October 1986 study of Charleston AFB, and the December 1986 study of Travis AFB.

Iowa Army Ammunition Plant. The study of the Iowa Army Ammunition Plant evaluated the capability of the plant's transportation system to support its two-fold mission: "(1) to load, assemble, and pack ammunition items, and (2) to perform special mission assignments, such as research and development and special projects" (13:4).

The analysis showed that the plant has nearly twice the transportation capability required by current mobilization plans (13:36). This finding provides new direction for planning and budgeting programs by showing specific areas of excess capability and potential for cost savings (13:37).

Defense Construction Supply Center--Columbus. The study of the Defense Construction Supply Center at Columbus, Ohio evaluated the capability of the Center's transportation system to support its mission as a military supply depot (9:35). Specifically, the Center is responsible for buying, managing, storing, and shipping construction materials and equipment, vehicle repair parts, and weapon system parts for the U.S. military (9:35). The Center supports 488 weapon systems, 386,000 items, a maintenance repair/ rebuild activity, and a storage program for DOD-owned industrial equipment (9:35).

Analysis of the Center's transportation system showed that the Center's rail and motor capability "substantially exceed mobilization requirements" (9:70). Further, the report showed how documentation processing would limit the Center's ability to process wartime levels of cargo (9:70).

The report went on to recommend re-evaluation of a $2.15 million plan to maintain the Center's entire rail system (9:70). Three alternative rail maintenance plans were provided by the MTMC engineers, each offering substantial savings to this Defense Logistics Agency-operated supply center (9:70-71).

Indiana Army Ammunition Plant. The third application of MTMC's methodology reviewed for this investigation was a study of the December 1985 study of the Indiana Army Ammunition plant. The primary mission of this plant is to produce propelling charges for three types of weapons (10:56). Other activities include renovating explosives storage containers and maintaining its inactive ammunition production facilities (10:56).

The findings for this plant's transportation system reveal that seven key "transfer and palletization docks . . . cannot meet mobilization requirements" (10:156). To resolve this shortfall, the report identified three construction options for plant officials to evaluate (10:156).

Other findings from this study show that the plant's tractor fleet may be insufficient and that a large supply of spare batteries are needed for the electric forklifts to maintain the current level of capability (10:156-157).

Seymour-Johnson Air Force Base. According to this report:

> The main mission of Seymour-Johnson AFB is to provide support to the 4th Tactical Fighter Wing stationed there. In support of this mission, the installation receives fuel, warehouse supplies, and ammunition and also stores and ships Air Force vehicles destined for overseas locations [21:9].

The purpose of the study was to evaluate the surface transportation system of the base. Major transportation activities were identified as follows:

> [1] Overseas vehicle movement.
> [2] Warehouse supply and delivery.
> [3] Fuel receipt.
> [4] Ammunition delivery.
> [5] Vehicle storage/preparation for shipment.
> [6] Warehouse operations (including unloading, storing, and loading aircraft engines, tools and bin-type items).
> [7] Delivery of fuel by pipeline, rail, or truck.
> [8] Unloading and storage of ammunition [21:43].

The report showed that the base can meet its current motor, rail, and fuel delivery mobilization requirements (21:43-44). In addition, the MTMC engineers provided several recommendations to ensure adequate capability is maintained, including: upgrade of the base rail network, additional training for rail switching crews, additional training for freight transportation personnel involved in rail blocking and bracing activities, and periodic inspection of fuel delivery capability by rail (21:45).

<u>Charleston AFB South Carolina</u>. The primary objectives of the Charleston AFB study were to determine: (1) the maximum capability of the surface transportation system during current and mobilization conditions; (2) the ability of the base to receive fuel by rail and truck; and (3) improvements to base assets which would increase transportation capability (20:4).

At the direction of Hq USAF, the study did not address cargo or passenger aircraft operations. However, the report did focus on rail activities for the supply and fuel facilities; truck activities in supply, air freight, and the ammo and fuels depots; and intra-base movement between supply and air freight (20:4).

The actual capability analysis is classified and is not discussed in the report (20:28). However, some significant shortfalls in capability were found in truck receiving and intra-base cargo movement. First, the study recommended procurement of additional portable ramps to offset the receiving shortage. It also urged purchase of three additional trailers to eliminate the intra-base movement shortfall. In addition, the analysis advocated purchase of five additional gas forklifts to overcome a shortfall in rail unloading operations. Finally, the study pointed out that in a mobilization scenario fuel and freight rail operations would not be able to take place simultaneously due to the size of the track network (20:47-49).

Travis AFB California. The Travis study was conducted under the same parameters as the Seymour-Johnson AFB and Charleston AFB analyses in that it did not consider airlift operations. Its purpose was to determine the maximum capability of the surface transportation system and to identify improvements that could increase current transportation system capability (14:4). Again, actual analysis of wartime requirements is classified; however, key findings highlighted in the report include: sufficient receiving capability in base supply, a shortage of forklifts for ammunition activities, and lack of dedicated ramps for flatbed loading and unloading operations (14:44-45).

Summary

This literature review surveyed three approaches to analyzing a transportation system by defining a transportation system and the concept of transportation capability. This chapter also outlined three approaches to measuring capability--transportation systems analysis, transportation engineering, and the MTMC TEA methodology. Further, it provided a detailed description of the MTMC methodology and summarized the results of six applications of the methodology to the surface transportation systems of Army installations and Air Force bases. Since the TEA approach has not yet been applied to air terminal functions, the next chapter will describe the methodology used in applying the Army's assessment tool to the air transportation operations of a sample Air Force base.

III. Methodology

Overview

This chapter describes the data collection techniques utilized to answer the investigative questions from Chapter I. The investigative questions were derived from the research objective which was to expand MTMC's methodology as the basis for a more complete Air Force transportation capability assessment tool.

Research Technique for Investigative Questions One and Two

The initial investigative questions asked, "What is transportation capability?" and "What are the principles involved in measuring transportation capability?" A review of the literature was conducted to document research findings and to present the views of expert transportation analysts. The texts of Marvin L. Manheim, editor for the Center for Transportation Studies of the Massachusetts Institute of Technology, and William W. Hay, Professor of Railway Civil Engineering at the University of Illinois, provided sound definitions of transportation capability and effectively clarified the principles involved in measuring that capability. These concepts were fully discussed in Chapter II, the Literature Review.

Research Technique for Investigative Question Three

The third investigative question asked, "What information has been gained as a result of applying the TEA style of analysis to DOD installations?" Research for this information was conducted through a literature review of published MTMC TEA reports. These reports are available through the Defense Technical Information Center (DTIC). The significant findings of these transportation capability assessments were presented in Chapter II.

Research Technique for Investigative Question Four

The fourth investigative question asked, "What is an effective technique for measuring air transportation capability?" Four steps were utilized in the process of this investigation: (1) research for the details of Davis' methodology; (2) selection of a representative Air Force base to analyze; (3) application of the TEA regimen; and (4) application of the principles of the TEA methodology, transportation systems analysis, and transportation engineering to those components of air transportation not investigated by the researchers of the Transportation Engineering Agency.

Data from the first step, researching the methodology, was incorporated in Chapter II. In the second step, a representative Air Force base was recommended and approved by the thesis advisor, and transportation experts at the Transportation Engineering Agency, the Air Force Logistics Management Center, Headquarters Military Airlift Command, and HQ USAF/LET. The base will remain unnamed in this investigation to preclude inadvertent release of sensitive information. However, each transportation authority cited herein felt the base studied was representative of the air transportation focus required for this thesis. Further, each transportation authority felt the model developed from this base would be applicable to most other Air Force bases.

The third step to investigative question four was to apply the TEA regimen. This phase required four research techniques. First of all, information was collected in personal interviews with base transportation experts in the following positions: transportation squadron commander, aerial port squadron commander, air/surface freight officers and noncommissioned officers (NCOs), base traffic management superintendent, and transportation plans officers and NCOs. Transportation experts in the positions of deputy commander and assistant for air transportation, and chief of transportation were also consulted. Personal interview was the best instrument for this step because telephone interviews and survey instruments would have fallen short of providing the necessary depth of detail (12:160). In addition, individuals in these positions of base transportation expertise were uniquely qualified to provide the most complete response to the highly technical questions of MTMC's methodology (12:159).

Next, detailed data were collected through observation. Emory notes that observation is a valuable tool to supplement the interviewing process (12:157). Since the output of one step in Davis' methodology was a flow chart of base cargo movement, observation greatly enhanced the finished product.

To supplement the personal interviews and observations, a literature review of base level documents was conducted. Appropriate documents were selected with the guidance of the previously-mentioned base transportation experts. In addition, basic statistical analysis of data in these documents was accomplished through descriptive statistics, as outlined in the TEA procedures. The documents were not always selected from formal sampling techniques based on the recommendations of the local transportation experts. In one case, the most recent twelve months of monthly work load reports were provided. These reports were the best source to characterize the truck, aircraft, and tonnage flows of the base studied over the past year. Unfortunately, these reports did not provide sufficient detail needed to apply the methodology. Information on mean ground time, offload time, number of aircraft loading vehicles (K-Loaders), and cargo load characteristics was also required. Base transportation experts did provide additional data in the form of sixty days of scheduled aircraft missions and records of offload equipment utilized on fifty-two inbound missions. These data still lacked sufficient detail, so a non-random purposive sample of inbound aircraft offload information was taken. From six months of data on approximately 7200 inbound and outbound missions between January and June 1987, a sample of 103 offloads was selected based on the following criteria: representativeness of the current mix of aircraft types, an all-cargo inbound mission, representativeness of the current mix of rolling stock and full pallet loads, missions from ten days of each month, and complete information on the data sheet selected. Zikmund notes that there are occasions when nonprobability samples are appropriate (32:423). A condition for use is that ". . . an experienced individual selects that sample based upon some appropriate characteristic of the sample members" (32:425). In this case, the individual selecting the sample had been assigned to the base studied for twenty months and had over nine years of experience in the air transportation field.

The final analysis technique utilized in research for investigative question four was to apply the principles and procedures of the TEA methodology, transportation systems analysis, and transportation engineering to those components of air transportation not investigated by the researchers of the TEA. These principles and procedures are detailed in Chapter II, the Literature Review.

Summary

This chapter has described the procedures employed to expand MTMC's transportation capability assessment tool for a more complete evaluation of Air Force base transportation systems. Research techniques included literature review, personal interviews, observation, statistical analysis, and application of the principles of transportation systems analysis and transportation engineering. Chapter IV of this thesis will detail the results of the application of the Army's system of analyzing base transportation capability.

IV. Analysis

Overview

This chapter presents an application of the five steps of the TEA methodology to the movement of air inbound cargo onto, through, and out the gates of an Air Force base. The analysis is sequenced in the same manner as the TEA approach and built from the interpretation and applications of the TEA methodology presented earlier in Chapter II, the Literature Review. A key point to remember is that the methodology only measures the ability of a base to meet a given work load scenario. The steps of this assessment tool are designed to aid in developing representative work load characteristics which are applied to the aircraft flow of a particular scenario. Then, transportation engineering capability assessment models are applied to the characteristics for the measurement results. For each step, this application presents only the information relevant to the measurement of air transportation operations. The source of the data is also provided. Since the details of the individual steps are provided in Chapter II, they are only referenced in this chapter.

Step 1. Mission and Operations

In the Air Force applications cited earlier in this study, the TEA approach typically begins by summarizing a base's history and location. In addition, detailed maps of the installation's road system and transportation facilities are also included. To preclude revealing the identity of the base studied in this application, the base's history, location, and road network will not be included. However, this information could be provided to enhance results where confidentiality is not a factor. In any event, the history, location, and road network of the base studied were reviewed for this application. Information was available in documents maintained by Public Affairs and the base Historian.

Base Mission. Continuing with the general outline of procedures for the MTMC methodology, the next part of step one is to describe the base mission. Information for this step was available in several unclassified documents. They include Air Force and major command-unique regulations and the published Base or Wing history. Selection and interpretation of appropriate documents was facilitated by personal interviews with base transportation officials, as well as, the Base Historian and the Public Affairs officer.

The base studied in this thesis is involved in air transportation operations and engaged in activities such as loading and offloading cargo from aircraft and trucks, and receiving, prccessing, warehousing, and documenting cargo moved. According to several base transportation authorities, the predominate transportation mission of the base studied is to act as an import freight facility for resupply of Army and Air Force units and facilities located within the theater of operations.

Cargo Types. The next objective in step one was to identify the various types of cargo shipped onto the base studied. In a series of personal interviews, the Air Freight superintendent characterized the base's cargo in four ways: palletized (on 463L pallets and not requiring further handling for processing), break bulk (cargo which arrives on a 463L pallet, yet requiring breakdown for processing and onward movement), rolling stock (primarily Army equipment that must be towed or driven), and outsize (cargo that is so large it will only fit on a C-5).

For the purpose of this study, only three cargo types were used to determine capability (palletized, break bulk, and rolling stock). There was no base documentation nor expert opinion to verify specific information on outsize cargo. In addition, this study assumes that rolling stock is predominantly unit equipment for the Army and requires movement by a prime mover (towing vehicle) or driver with special skills. No distinction was made between these two types of rolling stock and no attempt was made to analyze the capability of the base to specifically handle them. However, a generalized rolling stock work load was quantified throughout this report.

Description of the various types of cargo by tonnage came from local forms and a planning assumption from two base transportation plans experts. The plans experts stated that the mix of contingency cargo tonnage was expected to be 80 percent palletized and 20 percent rolling stock. Information on break bulk and palletized cargo had to be identified as a percentage of total air inbound cargo, after the total had been reduced by 20 percent for rolling stock.

Of 791 pallets handled within the sampling period in June 1987, 198 or 25.03 percent were break bulk and 593 or 74.97 percent remained palletized. This data was consistent with the opinion of the base import freight experts.

When combined with the contingency assumption of 80 percent palletized and 20 percent rolling stock, the three types of cargo become delineated in tonnage as 20 percent rolling stock, 20.02 percent break bulk (.80 x .2503 = .2002), and 59.98 percent palletized (.80 x .7497 = .5998). Table 1 summarizes these assumptions about the types of cargo handled at the base studied.

Cargo Flow. Based on extensive personal interviews and observation of aircraft unloading and cargo processing

TABLE 1

SUMMARY OF CARGO TYPES

Cargo Type	Percent of Tonnage	Percent of Pallets
Rolling Stock	20.00	Not Applicable
Break Bulk	20.02	25.03
Palletized	59.98	74.97
Total	100.00	100.00

procedures, the flow chart in Figure 1 was developed. The process for developing this flow chart was to interview experts in flight line and cargo operations in an iterative manner and to make frequent observations of the actual flow of cargo. The first question asked was "How does cargo flow from the flight line through the cargo processing facilities and out the gate?" A drawing was then made from the verbal description. The drawing from each person interviewed was reviewed by the next person interviewed and expanded or modified, as required. Throughout the interview process each cargo processing expert interviewed was questioned at least twice. Officials in Air Freight and the Air Terminal Operations Center (ATOC) were the primary sources of information on the cargo flow depicted in Figure 1. Note that three vehicle fleets involved in this flow were not completely controlled by the base studied:

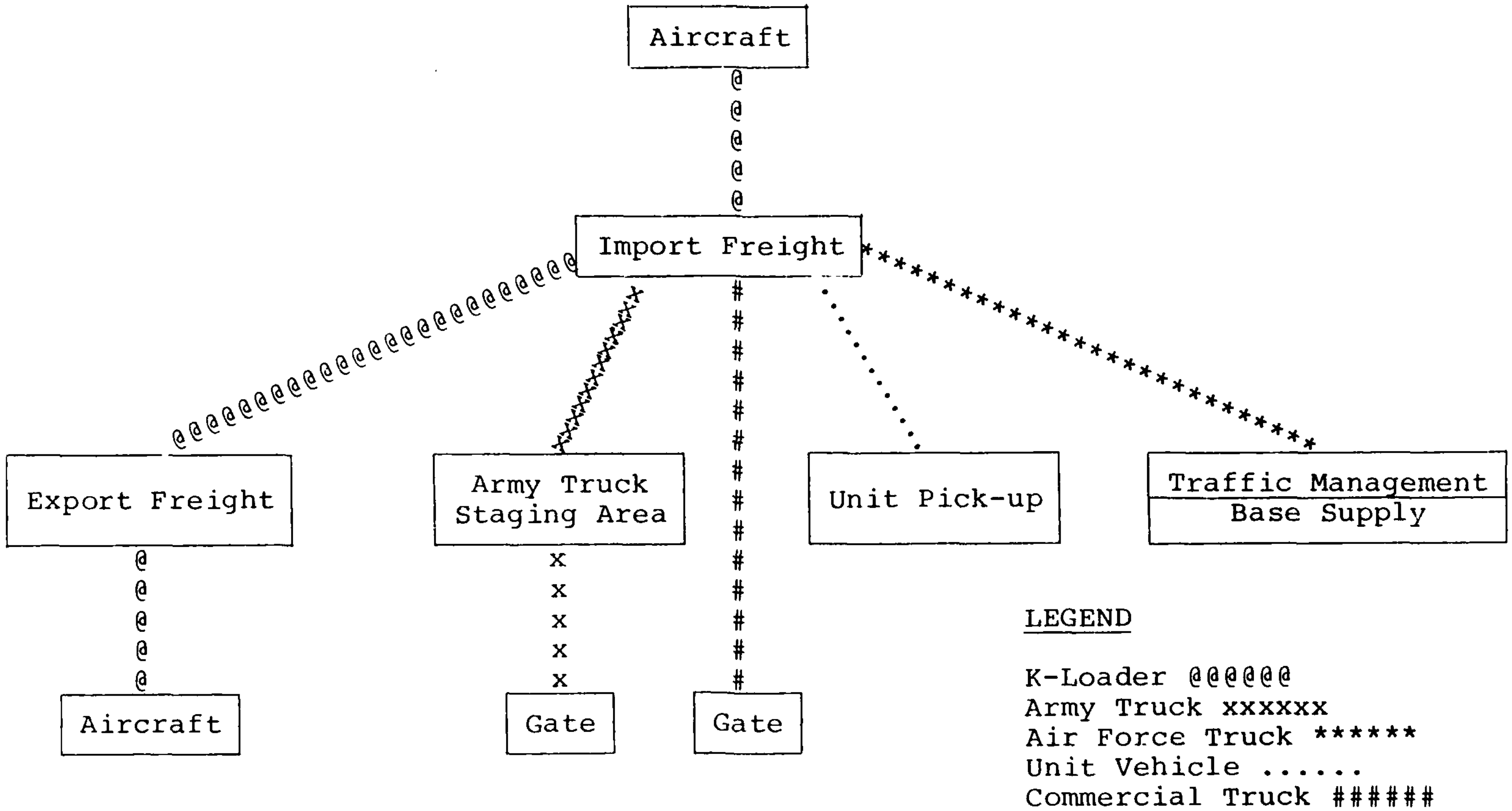

Fig. 1. Cargo Flow

the Army's fleet of semi-trailers, some of the unit vehicles, and the commercial trucks.

Step 2. Facilities and Equipment

This phase of analysis consists of an inventory of facilities and equipment and a review of assigned personnel.

Inventory of Facilities. Information for this inventory was extracted from the base aircraft parking plan, a personal interview with the airfield manager, local records, and personal interviews with aircraft and truck loading specialists. Table 2 depicts the capacity of Import Freight storage facilities, while Table 3 gives dimensions of the truck handling facilities of the base studied.

TABLE 2

STORAGE FACILITIES

Operation	Capacity
Import Air Freight Storage	34,707 sq ft
Import Air Freight Pallet Breakdown	7,800 sq ft

TABLE 3

TRUCK HANDLING FACILITIES

Operation	Dimensions
Surface Freight Truck Dock	91' x 9'
Import Freight Truck Dock	740' x 10'

Table 4 presents the available truck loading positions for Import Freight operations. Since the exact number of positions is not designated at this facility; these figures are subject to variation. In addition, Table 4 shows an estimated number of positions that could be utilized if truck loading operations were expanded along the entire Import Freight dock. Typically, these positions are not available due to common use of the dock with a tenant organization of the base.

TABLE 4

IMPORT FREIGHT TRUCK LOADING POSITIONS

Operation	Positions		
	Normal	-	Expanded
Flatbed	15	-	20
Semi-van Trailer	30	-	50
TMO Truck	1	-	1
Commercial Truck	3	-	3
Unit Pick Up Vehicle	1	-	1
Total	50	-	75

After cargo has been downloaded from the aircraft, the pallets are transported by 40K-loader to a temporary pallet storage yard. The break bulk pallets are later moved inside the freight building for further processing, while the palletized cargo remains in the yard. Table 5 shows the designated 463L pallet storage areas of the base studied.

TABLE 5

463L PALLET STORAGE CAPACITY

Operation	Positions
Primary Pallet Storage Yard	115
Extended Pallet Storage Area	75
Total	190

This storage capacity is supplemented by rollerized highline docks used mostly for processing of pallet trains when the dimensions of the cargo exceed the dimensions of a standard 463L pallet (88" x 108"). The import freight facility has eight of these rollerized docks each with a capacity of five pallets. In addition, twenty pallet positions are designated for temporary storage of palletized household goods near the Import Freight truck dock.

According to the airfield manager of the base studied, there are unlimited combinations of the various types of aircraft that can park on the flight line ramp. Selection of a generalized combination for the purpose of this study was limited by this fact. In addition, the base aircraft parking plan only designated places for military aircraft. A review of a sample of 103 arrivals showed that cargo aircraft arriving at this base included both military and civilian aircraft. The sample also identified relatively standardized parking places for commercial cargo aircraft. These locations were combined with the primary parking positions for each type of aircraft to build a generalization on the maximum number of parking spots for each type aircraft at the base studied. The results are shown in Table 6.

Inventory of Equipment. The sources for this information included personal interviews with squadron vehicle managers and research of local records. Table 7 provides a list of equipment assets required for this measurement tool. The table also shows the quantity of equipment available after consideration of the number assigned, the number in maintenance, and the number being utilized off station. The current in-commission rate of the 463L materials handling equipment was 71 percent despite a command standard of 87 percent.

TABLE 6

MAXIMUM AIRCRAFT PARKING POSITIONS

Type Aircraft	Max.	Limitation
C-130	27	If more than 14 C-141s are to park at the same time, the maximum number of C-130s is reduced to 24.
C-141	16	If more than 2 C-5s are to park at the same time, the maximum number of C-141s is reduced to 13.
C-5A/B	4	None.
B-747 (cargo)	2	If 1 B-747 arrives, then 1 DC-8 and 1 DC-10 parking spots are eliminated; if 2 B-747s arrive, then 2 C-141 or 1 C-5 parking positions are lost.
DC-8	2	If 2 DC-8s arrive, then 2 C-141 or 1 C-5 positions are lost; if only 1 DC-8 arrives, then 1 DC-10 or 1 B-747 position is eliminated.
KC/DC-10	1	None.

TABLE 7

MATERIALS HANDLING EQUIPMENT INVENTORY

Item	# Assigned	# Off Station	# in Maintenance	# Available
25K Loader	2	0	1	1
40K Loader	7	0	2	5
10K Forklift	15	0	3	12
Cochran Loader	5	4	1	0
LLL (TA-15)	2	0	1	1
C-5 Passenger Stair Truck	2	0	0	2
4K Forklift	18	0	3	15
6K Forklift	1	0	0	1

NOTE: The Import Freight operation has only four of the 10K forklifts and four of the 4K forklifts assigned.

Personnel Authorized and Assigned. According to the April 1987 Unit Manning Document (UMD), there are 401 military air transportation personnel authorized and 386 assigned to the base studied. However, it is important to note that the Army's methodology is not designed to measure the number of people required to perform a given work load, nor will it provide a measure of the amount of work load a given number of people can perform. Instead, it focuses on the productive hours of a facility of equipment subsystem.

Productive Hours. The MTMC technique assumes that twenty hours of productive time a day result from a twenty-four-hour, three-shift operation (14:1; 20:32; 21:32). Use of this assumption for the base studied was validated in personal interviews and agreed to by all base transportation experts; thus it is used to support computations in this study.

Step 3. Transportation Requirements

The process of defining transportation requirements began with a review of the current work load of the base studied. Extensive statistical analysis of the base's current work load provided detailed information on the characteristics of material shipments received at the base studied. This detailed information was used later to support generalizations about the nature of a peak work load scenario against which the capability of the base was measured in Step Four.

Computations for Step Three were basically descriptive statistics (mean, mode, range) and were based on a thirty-day work month due to the nature of the work load of the specific base studied. TEA engineers generally use a twenty-day work month for measurement of the mean work load of CONUS bases.

Current Work Load. Data for this segment were extracted from the most recent twelve months of the Monthly Station Traffic Handling Report (June 1986 - May 1987) for the base studied.

Trucks per Day. Analysis of the segment of the monthly report detailing the current truck work load (loading and offloading of all trucks) showed the monthly mean of truck handlings was 1,533 trucks at 4,138.17 tons per month. Based on thirty work days per month, this equates to 51.1 mean daily truck handlings (1533/30 = 51.1) at 2.7 tons per truck (4138.17/1533 = 2.7). This tonnage figure was confirmed in a personal interview with the import freight NCOIC. However, this data should be interpreted with caution because it represents cargo that is loaded on government and commercial trucks for transportation off the base and cargo offloaded for export air freight operations. The data could not be broken down further due to insufficient detail of information maintained at base level.

Aircraft per Day. Table 8 provides a summary of the average monthly inbound cargo aircraft handled at the base studied.

TABLE 8

CURRENT DAILY INBOUND AIRCRAFT WORK LOAD

Type Aircraft	Monthly Mean	Daily Mean
C-5	34	1.13
C-130	213	7.10
C-141	155	5.17
Narrow Body (commercial)	7	0.23
Wide Body (commercial)	14	0.46
Total	423	14.09

Tons per Day. Table 9 depicts the most recent twelve months work load in tons of air inbound cargo received at the base measured which resulted in a daily mean of 96.95 tons (2908.5/30 = 96.95).

Cargo Work Load Characteristics by Aircraft Type. The monthly work load report utilized for the previous analyses failed to provide sufficient detail to complete the measurement process. So, a sample of inbound aircraft

TABLE 9

CURRENT AIR INBOUND CARGO WORK LOAD

Month	Tons
June	2987
July	2502
August	3089
September	2997
October	2986
November	3317
December	2805
January	2141
February	2764
March	2955
April	3146
May	3213
Total	34902*

*NOTE: 34902/12 = 2908.50 tons per month.

data was examined to break down work load characteristics by aircraft type. The work load was differentiated by the seven types of military and civilian cargo aircraft that transited or originated at the base studied: C-141B, DC-8, C-130, DC-10, KC-10, C-5A and B, and the B-747. On some local forms, data on commercial aircraft types were grouped by narrow-body and wide-body cargo aircraft. In addition, very few KC-10s were handled during the time period sampled and none was offloaded; thus any information on

KC-10s and DC-10s was consolidated. C-5A model and B model aircraft data were also aggregated for this study.

Many attributes were computed to provide a basis for making sound generalizations about the current peacetime and contingency work load of the base studied. This is based on the assumption that the current work load of each Air Force base has unique characteristics that will form an adequate basis for measuring capability. Some of the areas detailed in the following text include identification of:

1. Types of aircraft carrying rolling stock

2. Tons per aircraft by type

3. The mix of rolling stock and pallets associated with each type of aircraft

4. The mean amount of rolling stock per aircraft type by pieces and weight

5. The mean number of pallets per aircraft type

6. The mean number of pallets that must be broken down (break bulk)

7. The mean number of flatbed and semi-trailer vans required to move the pallets and rolling stock

Of the aircraft types handled at the base studied, only three are capable of carrying rolling stock: C-130, C-141, and the C-5A/B. The following analyses fully discuss the rolling stock characteristics for these aircraft.

In addition, the analyses detail each of the attributes described above for each of seven types of aircraft handled by the base studied. This section then concludes with a summary of key daily work load characteristics for the base studied.

C-130 Work Load Characteristics. Further analysis of the monthly station traffic report showed that 50.59 percent of the total aircraft handled by the base were C-130s. From the sample of 103 offloads, 12 missions sampled were C-130s. Of the 12, six had rolling stock for a total of 50 percent. Of the six with rolling stock, three had no pallets or only rolling stock for a cargo load for a total of 25 percent.

Since some missions in the sample had both pallets and rolling stock, it was difficult to compute a mean weight for rolling stock. Thus, the standard pallet weight of 3500 pounds or 1.75 tons was subtracted from the total weight of the offload. Then, the remaining weight was divided by the number of pieces of rolling stock. Based on this assumption, computations on the sample data show the mean weight of a piece of rolling stock was 3537.25 pounds or 1.77 tons and the mean number of pieces of rolling stock on a C-130 was 2. In addition, the sampled C-130s off-loaded 19 pallets for a mean of 1.58 pallets per aircraft. The mean offload time was .66 hours using one 40K-loader on the average. The minimum scheduled ground time for a

C-130 was one hour and the mode of a sample of C-130 ground times was 17.83. And finally, the sample showed the mean amount of cargo offloaded per C-130 was 3.98 tons.

C-141 Work Load Characteristics. Further analysis of the monthly station traffic report showed that 37 percent of the total aircraft handled by the base were C-141s. From the sample of 103 offloads, 51 missions sampled were C-141s. Of the 51, six had rolling stock for a total of 11.8 percent. Of the six with rolling stock, two had no pallets or only rolling stock for a cargo load for a total of 9.8 percent.

Again, using the standard pallet weight of 1.75 tons, the mean weight of the rolling stock carried was estimated in the same manner as for the C-130. Computations on the sample data show the mean weight of a piece of rolling stock was 4.55 tons and the mean number of pieces of rolling stock on a C-141 was 2.17. In addition, the sampled C-141s offloaded 357 pallets for a mean of seven pallets per aircraft. The mean offload time was 1.05 hours using 1.72 40K-loaders per aircraft on the average. The minimum scheduled ground time for a C-141 was 2.25 hours and the mode of a sample of C-141 ground times was 3.25 hours. And finally, the sample showed the mean amount of cargo offloaded per C-141 was 14.86 tons.

C-5 Work Load Characteristics. Further analysis of the monthly station traffic report also showed that 8 percent of the total aircraft handled by the base are C-5s. From the sample of 103 offloads, 23 missions sampled were C-5s. Of those, 5 had rolling stock for a total of 21.74 percent. Of the five with rolling stock, two had no pallets or only rolling stock for a total of 8.7 percent.

Using the standard pallet weight of 3500 pounds or 1.75 tons, the mean weight of the rolling stock carried was estimated. Based on this assumption, computations on the sample data show the mean weight of a piece of rolling stock was 12.1 tons and the mean number of pieces of rolling stock on a C-5 was 2.8. In addition, the sampled C-5s offloaded 470 pallets for a mean of 20.43 pallets per aircraft. The mean offload time was 1.39 hours using 3.4 40K-loaders per aircraft on the average. The minimum scheduled ground time for a C-5 was 3.25 hours and the mode of a sample of C-5 ground times was 4.25 hours. And finally, the sample showed the mean amount of cargo offloaded per C-5 was 44.8 tons.

DC-8 Work Load Characteristics. From the sample of 103 offloads, 8 missions sampled were DC-8s. Of the eight samples, 83 pallets were offloaded for a mean of 10.38 pallets per aircraft. The mean offload time was

.97 hours using two 40K-loaders per aircraft on the average. The minimum scheduled ground time for a DC-8 was 2.33 hours and the mode of a sample of DC-8 ground times was 2.33 hours. The mean amount of cargo offloaded per DC-8 was 15.83 tons.

B-747 Work Load Characteristics. From the sample of 103 offloads, seven missions sampled were B-747s. The seven missions offloaded 278 pallets for a mean of 39.71 pallets per aircraft. The mean offload time was 2.13 hours using four 40K-loaders per aircraft on the average. The minimum scheduled ground time for a B-747 was 4.67 hours and the mode of a sample of B-747 ground times was 5 hours. The mean amount of cargo offloaded per B-747 was 79.89 tons.

KC/DC-10 Work Load Characteristics. Of the 103 samples, two were DC-10 missions. These missions carried 36 pallets for a mean of 18 pallets per aircraft. In addition, mean cargo load per aircraft was 27.16 tons.

Summary of Mean Daily Work Load. An aggregation of key elements from the preceding analyses describes the mean daily work load for the base studied. As Table 10 demonstrates, air inbound missions bring an average of 91.15 pallets per day. Figure 2 shows how these pallets can be broken down based on the data in Table 1 to compute daily movement of 31.88 trucks on the average. This movement is

TABLE 10

SUMMARY OF MEAN DAILY WORK LOAD

Type Aircraft	Daily Avg. Aircraft	Avg. # Pallets	Total Daily Pallets
C-5	1.13	20.43	23.08
C-130	7.10	1.58	11.22
C-141	5.17	7.00	36.19
Narrow (commercial)	.23	10.38	2.39
Wide (commercial)	.46	39.71	18.27
Total			91.15

Total daily pallets received	91.15
X percentage break bulk X	25.03%
Break bulk pallets	22.81
Palletized	68.34

68.34 / 4 (pallets per truck) = 17.09 trucks per day for palletized cargo

22.81 x 1.75 (tons per pallet) = 39.92 tons of break bulk

39.92 / 2.7 (tons per truck) = 14.79 trucks per day for break bulk

17.09 + 14.79 = 31.88 trucks daily mean work load

Fig. 2. Computations Converting Pallets to Trucks

based on the TEA's assumption that the standard weight of 463L pallets of cargo is 3,500 pounds or 1.75 tons. Standard pallet weight was utilized to differentiate break bulk pallets for shipment by 40-foot tractor trailer van from the pallets not broken down which are shipped by flat bed truck (20:44; 14:28).

Peak Work Load Scenarios. As previously mentioned, MTMC's technique generally requires use of a classified war plan tasking to test the capability of a base. This thesis uses an alternative approach. Through personal interviews with base transportation experts, appropriate scenarios were solicited. Each expert was asked to provide an unclassified, demanding, creative, and realistic scenario to test this capability tool. Of the scenarios presented by key base transportation personnel, only one was appropriate for testing with this capability assessment tool. Each response is discussed below.

Scenario 1. This proposal was from the Deputy Commander for Air Transportation: "What work load can a core team of 80 people handle for four consecutive days?" This scenario was not an appropriate test for the Army's methodology because it is not designed to measure the work load of a specific number of people. In fact, the MTMC approach uses an assumption that sufficient personnel are available to maintain twenty-four-hour a day operations.

Instead, this scenario does offer an area for future research; namely that of linking manpower engineering principles with the transportation engineering models presented in the MTMC assessment tool to measure the work load potential of a given number of people.

Scenario 2. This proposal was from the OIC and NCOIC of ATOC: "We need a decision tool to evaluate the maximum flight line work load (loading/offloading of aircraft) during a two to four hour time given a changing amount of resources and changing time constraints." Again, this scenario didn't provide a work load to test the measurement tool. But it does give a valid idea for further research in the use of a decision support system to meet this need.

Scenario 3. This proposal was from the OIC and Superintendent of Air Freight: "Given that the cargo flow of this Air Force base (an overseas aerial port) is much like a funnel with greater flight line capability than cargo processing capability, then at what point does the inbound cargo flow slow down the cargo flow out of the cargo processing facility?" This scenario requires more sophisticated modeling analysis than the Army's capability assessment tool provides. It's possible that a simulation model would be the more appropriate measurement device, if sufficient statistical sampling data were available. In summary, evaluation of this scenario is beyond the scope of this thesis.

Scenario 4. This scenario was also presented by the OIC and Superintendent of Air Freight: "How much cargo can the Import Freight operation handle in a 48, 72, or 96 hour scenario?" This scenario is best answered by a warehouse simulation model. It does not provide sufficient work load data to compute with the Army's measurement system and is beyond the scope of this thesis.

Scenario 5. This situation was presented by the assistant deputy commander for Air Transportation: "I think the REFORGER redeployment flows are pretty demanding scenarios, so how about testing a 30-day flow of 20 C-141s, 6 C-5s, 4 B-747s, 4 DC-8s, and 25 C-130s?" This scenario did provide sufficient detail to apply the methodology and is fully developed in the remainder of Step Three.

Receiving Requirements. The aircraft flow discussed in Scenario Five is what MTMC terms "receiving requirements" for the scenario to be tested. In narrowing the scope of this application, only the inbound or offload portion of this scenario will be evaluated in the remaining steps.

Material Requirements. The ultimate purpose of this step was to identify available modes of shipment for the material received, specify typical shipment sizes, and translate the resulting requirements into trucks, aircraft, or railcars per day. Specifically, this meant translating the aircraft daily flow into the three cargo types identified in step one and estimating the average number of trucks required to move inbound cargo off the base.

First, the scenario to be tested was converted from an aircraft flow to the three types of cargo: palletized, break bulk, and rolling stock. Table 11 shows the computation into total tons per day which converts the total into tons of rolling stock based on the percentages of Table 1. Since the mean total weight is 1048.38 tons, rolling stock would equate to 20 percent of the total or 209.68 tons (1048.38X.20 = 209.68).

Next, the total daily pieces of rolling stock are computed in Table 12 by determining the number of aircraft expected to arrive with rolling stock and multiplying the result by the mean pieces per aircraft type as determined in the current work load characteristics analysis completed earlier in this step. Table 12 shows the daily rolling stock work load for Scenario Five is 33.85 pieces.

Table 13 shows the computations for determining the number of pallets Scenario Five would bring into the base. Based on the mean number of pallets per aircraft

TABLE 11

SCENARIO FIVE--ROLLING STOCK TONNAGE

Type Aircraft	# Aircraft	X	Mean Tons (Per Aircraft)	=	Total Tons
C-141	20		14.86		297.20
C-130	25		3.98		99.50
C-5	6		44.80		268.80
B-747	4		79.89		319.56
DC-8	4		15.83		63.32
Total	59		--		1048.38

TABLE 12

SCENARIO FIVE PIECES ROLLING STOCK

Type Aircraft	Number Aircraft	X	Percent with Rolling Stock	=	Number with Rolling Stock
C-141	20		11.80%		2.4
C-130	25		50.00%		12.5
C-5	6		21.74%		1.3
Type Aircraft	**Number with Rolling Stock**	**X**	**Mean Pieces Rolling Stock**	**=**	**Total Pieces Rolling Stock**
C-141	2.4		2.17		5.21
C-130	12.5		2.00		25.00
C-5	1.3		2.80		3.64
Total Pieces Rolling Stock per Day					33.85

TABLE 13

SCENARIO FIVE--PALLETS

Type Aircraft	Number Aircraft	Mean # Pallets	Total Pallets
C-141	20	7.00	140.00
C-130	25	1.58	39.50
C-5	6	20.43	122.58
B-747	4	39.71	158.84
DC-8	4	10.38	41.52
Total Pallets	-	-	502.44

type determined earlier, this scenario would result in a work load of 502.44 pallets. A breakdown of these pallets shows that 125.76 would be break bulk and 376.68 would remain palletized for onward movement. By converting the break bulk pallets into tons and dividing the result by the mean tons per truck (2.7 as computed earlier), the equation in Figure 3 shows 81.51 mean trucks per day would be required to move the cargo off the base. In addition, 94.17 trucks per day would be required to move the remaining pallets since each flatbed truck carries a maximum of four pallets. The total requirement for trucks per day is 175.68 as shown in Figure 3.

Intra-base Movement. This thesis focuses on airfreight import operations predominantly; more specifically,

Total pallets	502.44
X percentage break bulk	X 25.03%
Break Bulk Pallets	125.76
Remain Palletized	376.68

376.68 / 4 (pallets per truck) = 94.17 trucks per day for palletized cargo.

125.76
X 1.75 tons per pallet
220.08 tons / 2.7 (tons per truck) = 81.51 trucks per day for break bulk.

Total trucks per day = 94.17 + 81.51 = 175.68

Fig. 3. Computations for Daily Truck Work Load

this involves cargo that comes into the base by aircraft and moves out by truck. So, the five primary activities of intra-base movement may be classified as flight line (off-loading of aircraft), transfer of pallets and rolling stock from the flight line to temporary storage, transfer of break bulk pallets from temporary storage to the processing area of the warehouse, transfer of the individual break bulk pieces from the processing area of the warehouse to storage bays (by final destination), and loading of trucks for movement off the base. According to the MTMC approach, each activity should be measured individually. The following subsections describe the movement requirements for each of the activities described above.

Activity 1. Each aircraft in the scenario must be downloaded within the confines of its designated parking area. The download primarily requires the use of 40K-loaders and prime movers (towing vehicles) for the cargo types fully described in Tables 11, 12, and 13. In addition, the download of commercial aircraft requires the use of specialized equipment shown in Table 7. For the purpose of this study, only the capability of the 40K-loader fleet will be measured.

Activity 2. All of the cargo downloaded must be moved from the flight line to the temporary storage yard of the Import Freight facility. For Scenario Five, this includes 33.85 mean pieces of rolling stock and 502.44 mean pallets daily. The rolling stock is moved by prime mover or special driver. The exact amounts of rolling stock requiring prime movers or drivers is not available and so is not measured fully in this thesis. In reality, war plan taskings provide this level of detail; so a more complete evaluation of this requirement is possible, but is beyond the scope of this thesis. The 502.44 pallets require a minimum of 100.49 40K-loader trips (502.44 / 5 pallets per K-loader = 100.49). Although 25K-loaders were available on the base studied, only 40K-loaders were utilized in evaluating this scenario. This is because

25K-loaders primarily support baggage loading/offloading requirements for passenger operations.

Activity 3. Only break bulk pallets must be moved from the temporary yard storage area to the processing area within the import freight facility. According to the computations in Figure 3, 125.76 pallets must be moved; thus 125.76 mean daily 10K forklift trips are required to support this activity.

Activity 4. This activity requires movement of the individual shipments removed from the break bulk pallets during processing to the storage bays in the warehouse for each destination. According to the import freight specialists there are 30 to 50 pieces on a typical pallet, so the number of 4K forklift trips varies considerably. For the purpose of this application, no further measurement of shipments per pallet will be made as it is not a critical component of the methodology.

Activity 5. This activity employs two movement requirements: (1) from the storage bays to the truck docks (break bulk cargo), and (2) from the temporary storage yard to the truck docks (pallets). Again, the varying number of shipments makes it impractical to measure the number of trips required to move the break bulk cargo from the storage bays to the truck docks. The MTMC approach also leaves this aspect unmeasured and states that there are between 1 and 200 shipments in a truckload with the typical truckload having 15 shipments.

The cargo moving from the storage yard to the truck docks includes all the rolling stock and all the remaining pallets. If only one piece of rolling stock is moved at a time, then the daily requirement is for 33.85 trips, as mentioned in Activity Two. In addition, 10K forklifts must make 376.68 trips for palletized cargo as computed in Figure 3.

Shipping Requirements. The shipping requirements for Scenario Five were computed in Figure 3 and are summarized in Table 14. Based on the aircraft flow described in Scenario Five, 175.68 mean trucks per day would need to be loaded and driven off the installation.

TABLE 14

SHIPPING REQUIREMENTS FOR SCENARIO FIVE

Cargo Type	Mode of Shipment	Vehicles per Day
Palletized	Flatbed trailer	94.17
Break Bulk	Semi-trailer Van	81.51
Rolling Stock	Flatbed	Variable

Mobilization Production Schedule. The fourth part of Step Three is to combine requirements into a "mobilization production schedule" to test or measure capability against. Table 15 depicts the work load factors of Scenario Five as computed in the previous sections of Step Three.

TABLE 15

MOBILIZATION PRODUCTION SCHEDULE

Work Load Factor	Number of Mean Daily Units
C-130	25
C-141	20
C-5	6
B-747	4
DC-8	4
Pieces Rolling Stock	33.85
Break Bulk Pallets	125.76
Other Pallets	376.68
40K-Loader Trips	100.49 min
Trucks	175.68
10K Forklift Trips	502.44
Temporary Storage Yard Pallet Positions Required	502.44

Step 4. Subsystem Capability

The MTMC approach states that there are two subsystems, facilities and equipment, and contends that each requirement identified in the previous step utilizes both subsystems. Step 4 computes the capability of each subsystem to meet the stated requirement. Then, the subsystem with the least capability to meet a requirement defines the capability of the overall system.

To determine the outcome, the first task is to develop tables dividing the transportation requirements into individual activities such as loading, transporting, or unloading similar materials between the same origin and destination. The tables should also show which subsystems are utilized by the individual activities, the daily mobilization requirement for each activity, the building (if applicable) where the activity takes place, the type of cargo, and the purpose of the activity.

Identification of Subsystems. The facilities for inbound air transportation subsystems include the aircraft parking areas on the flight line, the temporary pallet storage yard, the import freight building processing and storage areas, roadways, gates to the base, and the truck docks. The equipment includes 40K-loaders, 10K forklifts, 4K forklifts, specialized commercial aircraft offloading equipment, and prime movers. The interrelationships of these subsystems are shown in Table 16. From Table 16, a measurement plan was developed for the capability of each of the activities listed. First, the aircraft parking limitations as shown in Table 6 were reviewed. In this case, as long as all the 59 aircraft of Scenario Five don't arrive at the same time, there is sufficient parking capability. Next, the ability of the 40K-loader fleet to support offload operations was measured. Actual measurement of this activity using the TEA's mathematical model required some overlap into measurement of activity two's requirement for 40K-loaders. This was because both activities were actually taking place at the same time. The second subsystem of activity two, pallet positions in the temporary storage yard, was also measured with the MTMC capability model.

Activity Three was dependent on the fleet of 10K forklifts and was measurable by the Army's approach; however, the capacity of the processing area for breakdown of break bulk pallets could only be measured by a review of the available area described in Table 2. The fourth activity was not measurable with the MTMC methodology since the number of shipments per pallet was highly variable. But again, the available storage areas for the individual bays were reviewed in Table 2.

TABLE 16

INBOUND AIR TRANSPORTATION ACTIVITIES AND SUBSYSTEMS

Activity Number	Location	Activity Description	Subsystems	
			Equipment	Facility
1	Flight Line	Unload Aircraft	40K-Loaders	Flight Line Parking
2	Yard	Transport to Temporary Storage	40K-Loaders	Pallet Spots in Yard
3	Import	Transport to Process	10K Forklifts	Processing Area
4	Import	Transport to Bay Storage	4K Forklifts	Storage Area
5	Import	Load Trucks	4K/10K Forklifts	Truck Positions
6	Base	Transport Off Base	Trucks, Roads	Gates

Activity Five was measured with the TEA methodology, although the computations relied almost exclusively on the productivity of truck loading operations on the truck dock and didn't seem to consider the capacity of the 4K forklifts to handle a limited number of shipments. If a sufficient sample of data on shipments per truck and shipments per 4K forklift trip could be collected, then this subsystem could be measured more precisely.

Activity Six offers unique considerations for this validation test of the Army's assessment tool. According to the computations in Figure 3, Scenario Five would generate a mean work load of 175.68 trucks per day. At the base studied, very few of the trucks handling outbound cargo were commercial. As Figure 1 shows, U.S. Army trucks are employed to move the outbound cargo flow of this base. This means that even though this capability assessment tool can estimate the mean number of trucks required per day, it cannot (in this case) measure the ability of the fleet of the Army's trucks to meet the required work load. Measurement of this subsystem would require information on the availability of the Army's truck fleet for a specific base. This is a critical consideration in evaluating the ability of the base to meet the work load of Scenario Five.

In each application of the methodology to Air Force bases to date, the roads and gates have not been restrictions on the flow of cargo out of the base. However, according to the Vice Wing Commander of the base studied, the ingress and egress of cargo trucks is a primary concern. In fact, an additional egress gate is in the planning stages now.

The next section details the capability analysis computations of each measurable subsystem.

Capability Analysis of Equipment and Facilities. The following computations utilize the mathematical models of Davis' methodology as discussed in Chapter II, the Literature Review. The models are restated in Figure 4.

Aircraft Offloading. Appendix A shows the computations for the capability of the base to offload aircraft in Scenario Five. The results show the requirement to offload 59 aircraft of five different types daily can be met when ground time is kept to a minimum. Actual capability ranges from 355.4 aircraft per day using the current mean offload time for each aircraft discussed in Step Three (and when there is no upload for the outbound mission) to 176.2 aircraft per day using the current scheduled minimum ground time (and no upload) to 36.6 aircraft per day using the modal ground time sampled from current schedules. The capability of 176.2 aircraft per day is the most likely one because the current minimum ground times approximate the ground times most often used in a contingency.

Capability model for a facility where only one transportation activity takes place:

$$CF = \frac{CV \times PT}{LT}$$

where

CF = facility capability
CV = total vehicle capacity
PT = estimated personnel productive time
LT = loading/unloading time for each activity

Capability model for a facility where more than one activity takes place:

$$W_i = \frac{REQ_i \times LT_i}{\sum_{i=1}^{n} REQ_i \times LT_i}$$

where

W_i = facility utilization factor for each activity
REQ_i = requirement for each activity
LT_i = loading/unloading time for each activity
n = number of activities
i = index number of the activity

The resulting W_i (facility utilization factors) are then incorporated in the following model:

$$CF = \sum_{i=1}^{n} \frac{W_i \times CV_i \times PT}{LT_i}$$

Fig. 4. Capability Models

The analysis in Appendix A also shows that the base could not offload the Scenario Five aircraft flow at the modal ground time scheduled. This is because the mode includes the peacetime factor of crew rest currently scheduled at the base studied. Thus, the limiting factor of this subsystem is the amount of available ground time.

40K-Loader Fleet. According to Davis' methodology, the capability of materials handling equipment (MHE) is analyzed by estimating the productive time needed to meet requirements; in other words, by comparing the equipment's available productive time to its required productive time. The MTMC approach views the factors of MHE in terms of loading and unloading time only. However, if this view were used to evaluate 40K-loader work load, it would not consider the transport time from the flight line to the temporary storage yard. So this analysis computes the capability of the 40K-loader fleet in the same manner that the Army's methodology measures a vehicle fleet.

The key factors for the analysis shown in Appendix B were the unloading time and transport time required for the mean number of trips estimated for Scenario Five. To convert the aircraft work load into the amount of 40K-loader hours required, this application first compared the mean number of 40K-loaders used per aircraft type to the mean number pallets per aircraft type. Since each 40K-loader can carry five pallets, the procedure used was to multiply the mean number of K-loaders by five. If this number was equal to or less than the mean number of pallets per aircraft divided by five, then the result was the number of trips per aircraft type. If this number was greater than the mean number of pallets divided by five, then the larger number represented the number of trips per aircraft type. The number of trips per aircraft type was multiplied by the mean transit time of .22 hours (from the aircraft to the temporary storage yard and back to the aircraft). These times were added to the product of mean offload time per aircraft type and number of aircraft in Scenario Five to arrive at the total productive time required of 88.82 hours.

To compute the available hours of the currently assigned 40K-loader fleet, this application used a type of sensitivity analysis. As stated in Step Two, there are seven 40K-loaders currently available with a 71 percent in-commission rate. This means that 71 percent of the time, only five K-loaders would be available. Since the command standard for the base studied is 87 percent, the sensitivity analysis computed availability in six situations where five, six, or seven K-loaders would be in use at twenty or twenty-four hours of personnel productivity.

The results show that there are sufficient 40K-loaders available to meet the total productive time required for Scenario Five. Sensitivity analysis shows that between 100 and 168 hours of productive time would be available from the fleet compared to the requirement of 88.82 hours.

Temporary Pallet Storage Yard. The following analysis shows that given a complete turnover of pallets every twenty-four hours in 190 pallet positions of the storage yard, there is insufficient capability to handle the pallet work load of Scenario Five. The model used for this analysis considered the number of pallets other than break bulk as the amount required for storage (378.68 pallets as shown in Table 15). Then, using the single activity formula of Figure 4, the result is that only 158.33 pallets can be stored each day (190 X 20 / 24 = 158.33). This product is very close to the current daily work load requirement of 101.05 mean pallets per day. Thus, the capability of the storage yard should be expanded.

10K Forklift Fleet. The analysis of 10K forklifts in Appendix C shows that under ideal conditions of a 100 percent in-commission rate, the capability of the 10K forklift fleet is barely sufficient to meet the work load requirements of this scenario. Under more realistic conditions (71 or 87 percent in-commission rate), there is insufficient capability. The actual capability ranges from 56.8 hours to 96 hours against the requirement for 80.4 hours of productive time.

4K Forklift Fleet. Appendix D provides an analysis that shows there is insufficient capability for the 4K forklift fleet to meet the requirements of Scenario Five. Sensitivity analysis of six possible conditions support this finding. Even the most ideal availability conditions (100 percent in-commission at 24 hours of productive time) provide only 96 hours of availability where 288.78 mean daily hours are required. The range of capability is from 56.8 hours to 96 hours.

Truck Loading Facility. The analysis of this facility in Appendix E shows there is sufficient capability to handle the mean daily truck work load of Scenario Five provided the Army has enough trucks available. Specifically, the truck loading subsystem has the capability to load 460.71 trucks per day against the requirement for 175.68 trucks per day. However, this analysis should be interpreted cautiously. First, consideration should be given to the number of 4K forklifts available for this work load. As the previous analysis showed, there is insufficient 4K forklift availability. In addition, a work load of 460.71 mean trucks per day may require more personnel than the Import Freight operation currently uses. And finally, consideration should be given to the limited amount of dock space available for maneuvering of forklifts. According to the Import Freight NCOIC, only two to three trucks are normally loaded at one time to reduce congestion on the dock. Thus, the actual capability of this subsystem may be much less than computed.

Step 5. Conclusions and Recommendations

The final phase of transportation capability analysis consists of building a comparison table of requirements and subsystem capabilities; identifying those subsystems that do not have sufficient capability, especially the one that is the weakest link; and recommending improvements to improve or modify capability. Table 17, the Mobilization Production Schedule, is presented here to review the basic requirements of Scenario Five. Then, Table 18 summarizes subsystem activity requirements and the capability computed in Step Four. It also shows capability for the range of conditions tested in the sensitivity analyses performed to validate the model's results.

Identify the "Weak Link" Subsystems. The subsystem with the least capability to meet its mean daily work load is the 4K forklift fleet. Given the aircraft flow of Scenario Five, the 4K forklift fleet can only meet about 20 percent of requirements. Three other subsystems fail to provide enough capability to meet the requirements of scenario five. aircraft unloading, temporary pallet storage, and the 10K forklift fleet. When aircraft ground time is equal to the current mean offload time, there is

TABLE 17

MOBILIZATION PRODUCTION SCHEDULE

Workload Factor	Number of Mean Daily Units
C-130	25
C-141	20
C-5	6
B-747	4
DC-8	4
Pieces Rolling Stock	33.85
Break Bulk Pallets	125.76
Other Pallets	376.68
40K-loader Trips	100.49 minimum
Trucks	175.68
10K Forklift Trips	502.44
Temporary Storage Yard Pallet Positions Required	502.44

TABLE 18

SUMMARY OF SUBSYSTEM REQUIREMENTS AND CAPABILITY

Subsystem	Daily Mean Requirements	Range of Capability Minimum	Range of Capability Maximum
1 - Aircraft Offloading	59 Aircraft	36.60	355.40
2 - 40K-Loader Fleet	88.82 Hours	100.00	168.00
3 - Temporary Storage Yard	376.68 Pallets	158.33	--
4 - 10K Forklift Fleet	80.40 Hours	56.80	96.00
5 - 4K Forklift Fleet	288.78 Hours	56.80	96.00
6 - Truck Loading	175.68 Trucks	460.71	--

insufficient time to handle the work load of scenario five. In addition, there are inadequate temporary pallet storage positions to accommodate the flow of pallets. Finally, the 10K forklift fleet also fails to meet the requirements of the peak work load scenario tested. The next section offers suggestions to overcome these shortfalls.

Make Recommendations to Improve/Modify Capability. Within the aircraft [illegible] subsystem, time is the key element. As previously discussed, this subsystem only has sufficient capability when ground time is adjusted to allow a smooth flow [illegible] available parking positions and when [illegible] times are used. Thus, management [illegible] is critical in peak work load [illegible].

[illegible] 4 K-loader fleet appears to [illegible], the added dimen-[illegible] vehicle availablity. [illegible] simulate this outbound [illegible] would be required. [illegible] optimal condi-[illegible] for 24 hours would only provide [illegible] capability. However, verification of the [illegible] this estimate was beyond the scope of this thesis. [illegible] define the impact of air outbound [illegible], this methodology should be tested with appropriate data.

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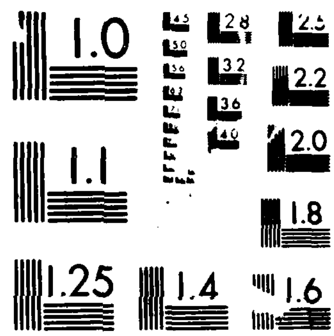

MICROCOPY RESOLUTION TEST CHART

1963-A

The limitations of the temporary pallet storage yard offer insight into the importance of building plans for use of paved storage areas, as well as the dunnage (three pieces of 3 x 5 x 88 inch lumber) required for proper support of each 463L pallet. If Scenario Five were a real world tasking, additional pallet storage area would be needed--at least enough for a daily mean of 218.35 more pallet positions.

The 10K forklift fleet would be adequate if approximately two more vehicles were made available. Table 7 shows that 15 forklifts are available to air transportation operations; so local plans should be developed to shift the fleet as peak work load conditions allow.

To handle the work load of Scenario Five, approximately 16 additional 4K forklifts are required. Table 7 shows that only 18 are assigned to the entire air transportation operation, thus it may not be appropriate to realign assets. Authorizations should be reviewed and plans for local procurement should be made in the event of a short notice contingency requirement such as Scenario Five.

Capability analysis of the truck loading facility shows there is excess capability in terms of loading positions. Since it is not practical to reduce the area of truck docks, a plan should be developed to facilitate efficient loading operations. This plan could incorporate a concept of designating appropriate truck loading positions to reduce congestion of the dock and truck parking areas. Also, this excess capability may distort the fact that a mean 175.68 trucks per day could be loaded in a peak work load like scenario five. Since this greatly exceeds the current daily work load of the base (as computed in Figure 2), transportation officials should closely coordinate this information with Army organizations managing the truck fleet. If insufficient trucks are available to meet this work load flow, other subsystems could be seriously affected.

Summary

This chapter has presented a detailed application of Army's methodology to the air inbound cargo flow of a sample Air Force base. The capability analysis revealed forklift and storage shortfalls, as well as, excess capability in truck loading positions. Sensitivity analysis was conducted in nearly all of the capability models to provide an internal validation.

This analysis demonstrated that the Army's methodology is sufficiently flexible to measure the air inbound cargo flow of an Air Force base. The final chapter of this thesis will provide additional conclusions from this application, as well as recommendations for further research.

V. Conclusions

Introduction

Base transportation planners, managers, and operators have long utilized "gut feeling" to support expert judgements on the capability of the transportation system they direct. This is primarily due to the nature of the cargo handling operation where there is no such thing as an average size shipment and very often there is no such thing as an average aircraft load. However, measurement of transportation capability is critical to ensure full support of military operations. Precise measurement of transportation capability has been elusive and often based on generalizations that may or may not provide adequate representation. The methodology presented in this study also uses generalizations, but an added dimension is precision in defining relationships of the various subsystems of transportation: facilities and equipment. In addition, the generalizations of this capability assessment tool are based on the Transportation Engineering Agency's ten years of experience in applying the methodology to surface transportation systems.

Research Conclusions

The external validity of TEA's measurement tool has already been demonstrated in its use to measure surface transportation capability of both Army and Air Force installations. This thesis only provides additional proof of the technique's validity through this application to air transportation subsystems. Thus, it can be said the methodology has flexibility to model most components of the transportation system and assess the capability of a military installation to meet mission requirements within the limits of available equipment and facilities. As a management tool it provides an added bonus of educating the user. The basic concept learned from using this methodology is a new awareness of the intricacies of a base's transportation infrastructure. This new level of awareness can lead to better management of critical base level resources as well as improved combat capability for U.S. military forces.

The Army's methodology is relatively easy to use since it follows a heuristic approach to problem solving in its five-step technique. It can also be considered a valid predictor model since the final outcome is, in essence, a prediction of a base's ability to accommodate a given work load. Furthermore, it is a comprehensive model that permits use of sensitivity analysis to provide a range of values for more precise capability assessment.

As a model, it is dynamic and adaptable. Few adjustments were required to measure the Air Force-unique functions of air transportation operations. The methodology expertly simplified the complex system of air cargo operations without making unrealistic assumptions. In addition, most of the assumptions used were based on standard war planning strategies.

In summary, it worked. The result is that base level transportation planners now have a tool to better evaluate contingency scenarios as they are tasked. The flexibility of the methodology also offers a means to evaluate work load policies. In war and peacetime, time is a precious commodity and policies that don't provide increased capability should be identified and evaluated.

As previously mentioned, this assessment technique is an aid to testing the feasibility of war plans. If sufficient information is maintained at the higher headquarters level, it is possible that peak work load scenarios could also be tested before they are ever tasked to specific bases.

In many of the past applications to DOD installations, this model has proven to be a guide for better allocation of equipment and facility expenditures. The results of Chapter IV show this benefit continues for assessment of air transportation operations, also.

Pros and Cons of Using the New Methodology

Potentially, there are several advantages to using this assessment model. First, it provides a means to reduce uncertainty and risk in the Defense Transportation System by quantifying resource requirements and capabilities. In addition, application of the methodology promotes cost savings to the DOD. Without a measurement tool, only a complete exercise of the peak work load scenario could provide insight into system capabilities. Military exercises are very expensive and may not fully simulate all the wartime variables that affect a transportation system. A systems analysis done in peacetime provides a relatively inexpensive and systematic method to assess the entire base transportation system or parts of the system without the cost, time, and trouble of an exercise.

On the other hand, there are some limitations to utilization of the Army's methodology. First of all, it doesn't measure the number of people needed to support a given scenario. Manpower engineering models do provide some information in terms of human resources required and could possibly be linked to this transportation engineering and systems analysis approach as an avenue of future research.

Another area of concern is documentation. Under current operations, cargo doesn't move between activities until it has been accounted for. Yet, the TEA system of analysis doesn't consider the work load of documenting movement as a primary subsystem of transportation. In addition, the methodology doesn't provide a means of assessing the importance of communications in daily operations. As critical functions, documentation and communications affect the most vital resources of a transportation operation--time and information. No system can operate effectively without these resources.

Further Research

As previously mentioned, one area of future research could be to link manpower engineering principles and measurement techniques with this transportation system capability assessment methodology. Another area of potential use and research is passenger operations. It is possible that both the military and civilian assets used to support mobilization scenarios could also be measured with this model. Since this thesis has demonstrated use of the Army's methodology to air transportation operations, each of the war plans currently in effect could be evaluated for a more complete base level transportation feasibility estimate. As discussed in Chapter IV, the transportation engineering and systems analysis concepts of this methodology may also be a logical basis for building a decision support system tool for the daily work load assessments made in air terminal operations centers.

Since this methodology has only been applied to a few Air Force bases, recommend commissioning the Air Force Logistics Management Center, the MTMC Transportation

Engineering Agency, or Air University researchers to continue validation and refinement by application to other Air Force bases in the CONUS and overseas.

Summary

Despite the fact that users have traditionally not been able to adequately measure requirements, it's imperative now to identify those key elements of the current Defense Transportation System which may not be providing the level of responsiveness needed to ensure that Army, Air Force, DOD, and allied units will be supported when and where needed. This thesis has described a methodology with great potential to meet this requirement. It's available now for all Air Force bases to utilize and promote their readiness by measuring transportation combat readiness.

Appendix A: Computations for Capability of the Airfield Operations Subsystem

Aircraft Type	Activity Index(i)	Airfield Capacity (CV)	Requirement in ACPD* (REQ)	Productive Time (PT)	(LT^1) Mean Off-load Time (in hours)	(LT^2) Ground Time Minimum	(LT^3) Ground Time Mode
C-130	1	27	25	20	.66	1.00	17.83
C-141	2	16	20	20	1.05	2.25	3.25
C-5	3	4	6	20	1.39	3.25	4.25
C-747	4	2	4	20	2.13	4.67	5.00
DC-8	5	2	4	20	.97	2.33	2.33

*NOTE: ACPD means aircraft per day.

$$W_i = \frac{REQ_i \times LT_i^1}{\sum_{i=1}^{5} REQ_i \times LT_i^1}$$

$$W_1 = \frac{25 \times .66}{58.24} = .2833$$

$$W_2 = \frac{20 \times 1.05}{58.24} = .3606$$

$$W_3 = \frac{6 \times 1.39}{58.24} = .1432$$

$$W_4 = \frac{4 \times 2.13}{58.24} = .1463$$

$$W_5 = \frac{4 \times .97}{58.24} = .0666$$

$$CF(\text{flightline}) = \sum_{i=1}^{5} \frac{W_i \times CV_i \times PT}{LT_i^1}$$

$$CF = \left(\frac{.2833 \times 27 \times 20}{.66}\right) + \left(\frac{.3606 \times 16 \times 20}{1.05}\right) + \left(\frac{.1432 \times 4 \times 20}{1.39}\right)$$

$$+ \left(\frac{.1463 \times 2 \times 20}{2.13}\right) + \left(\frac{.0666 \times 2 \times 20}{.97}\right)$$

$$CF = 231.7909 + 109.897 + 8.2417 + 2.7474 + 2.7464$$

$$CF = 355.4235 \text{ ACPD}$$

$$W_1 = \frac{REQ_1 \times LT_1^2}{\sum_{i=1}^{5} REQ_i \times LT_i^2} = \frac{25 \times 1}{117.5} = .2128$$

$$W_2 = \frac{20 \times 2.25}{117.5} = .3830$$

$$W_3 = \frac{6 \times 3.25}{117.5} = .1660$$

$$W_4 = \frac{4 \times 4.67}{117.5} = .1590$$

$$W_5 = \frac{4 \times 2.33}{117.5} = .0793$$

$$CF(\text{flightline}) = \sum_{i=1}^{5} \frac{W_i \times CV_i \times PT}{LT_i^2}$$

$$CF = \left(\frac{.2128 \times 27 \times 20}{1}\right) + \left(\frac{.3830 \times 16 \times 20}{2.25}\right) + \left(\frac{.1660 \times 4 \times 20}{3.25}\right) + \left(\frac{.1590 \times 2 \times 20}{4.67}\right) + \left(\frac{.0793 \times 2 \times 20}{2.33}\right)$$

$$CF = 114.912 + 54.471 + 4.086 + 1.362 + 1.361$$

$$CF = 176.192 \text{ ACPD}$$

$$W_1 = \frac{REQ_1 \times LT_1}{\sum_{i=1}^{5} REQ_i \times LT_i} = \text{[illegible]}$$

$$W_2 = \frac{20 \times 3.25}{565.57} = .1149$$

$$W_3 = \frac{6 \times 4.25}{565.57} = .0451$$

$$W_4 = \frac{4 \times 5}{565.57} = .0354$$

$$W_5 = \frac{4 \times 2.3}{565.57} = .0163$$

$$CF(\text{flightline}) = \sum_{i=1}^{5} \frac{W_i \times CV_i \times PT}{LT_i^3}$$

$$= \left(\frac{.7881 \times 27 \times 20}{17.83}\right) + \left(\frac{.1149 \times 16 \times 20}{3.25}\right) + \left(\frac{.0451 \times 4 \times 20}{4.25}\right)$$

$$+ \left(\frac{.0354 \times 2 \times 20}{5}\right) + \left(\frac{.0163 \times 2 \times 20}{2.33}\right)$$

$$= 23.8684 + 11.3132 + .8489 + .2832 + .2798$$

$$= 36.594 \text{ ACPD}$$

SUMMARY

Capability in ACPD Based on		
Offload Mean Time	Ground Time Minimum	Ground Time Mode
LT^1	LT^2	LT^3
355.4	176.2	36.6

Appendix B: Computations for Air Inbound Capability of the 40K-Loader Subsystem

1. Daily Number of 40K-Loader Trips Required

Aircraft Index	Activity ACPD	ACPD	Mean # 40Ks per Aircraft	Mean Pallets per Aircraft	Total Trips
C-130	1	25	1.00	1.58	25
C-141	2	20	1.72	7.00	40
C-5	3	6	3.40	20.43	30
B-747	4	4	4.00	39.71	32
DC-8	5	4	2.00	10.38	12
Total					139

2. Estimate of 40K-Loader Fleet Productive Time Required (Using Mean Offload Time)

Activity Index (i)	Total Off-load Time (LT)	+	Total Transit Time (TT)	=	Total Productive time (PT)
1	16.50		5.50		22.00
2	21.00		8.80		29.80
3	8.34		6.60		14.94
4	8.52		7.04		15.56
5	3.88		2.64		6.52
Total Productive Time Required					88.82 hrs.

3. Estimate of 40K-Loader Fleet Available Time

# Assigned (N)	X	In-commission Rate (IC)	=	Expected Availability (EA)	X	Productive Time (PT)	=	Available Hours (AH)
7		71%		5		20		100
7		71%		5		24		120
7		87%		6		20		120
7		87%		6		24		144
7		100%		7		20		140
7		100%		7		24		168

Appendix C: Computations for Capability of the Import Freight 10K Forklift Fleet

1. Activity

Activity	Trips	X	Transport Time	=	Total Time (in hours)
Transport break bulk from yard to import	125.76		.08		10.06
Transport pallets from yard to import	376.68		.08		30.13
Offload K-loaders at yard and store	502.44		.08		40.20
Total Productive Time Required					80.40

2. Estimate of 10-K Forklift Fleet Available Time

# Assigned (N)	X	In-commission Rate (IC)	=	Expected Availability (EA)	X	Productive Time (PT)	=	Available Hours (AH)
4		71%		2.84		20		56.80
4		71%		2.84		24		68.16
4		87%		3.48		20		69.60
4		87%		3.48		24		83.52
4		100%		4.00		20		80.00
4		100%		4.00		24		96.00

Appendix D: Computations for Capability of the Import Freight 4K Forklift Fleet

1. Activity

Activity	Trips	X	Processing and Transport Time	=	Total Time
Transport break bulk cargo to bay storage	125.76		1		125.76
Transport break bulk cargo from bay storage and load trucks	81.51*		2		163.02
Total Productive Time Required					288.78

*Based on requirement to load 81.51 semi-trailer vans.

2. Estimate of 4K Forklift Fleet Available Time

# Assigned (N)	X	In-commission Rate (IC)	=	Expected Availability (EA)	X	Productive Time (PT	=	Available Hours (AH)
4		71%		2.84		20		56.80
4		71%		2.84		24		68.16
4		87%		3.48		20		69.60
4		87%		3.48		24		83.52
4		100%		4.00		20		80.00
4		100%		4.00		24		96.00

Appendix E: Computations for Capability of the Airfreight Truck Loading Facility Subsystem

1. $$W_i = \frac{REQ_i \times LT_i}{\sum_{i=1}^{2} REQ_i \times LT_i}$$

$$W_1 = \frac{94.17 \times .583}{258.68} = .2122$$

$$W_2 = \frac{81.51 \times 2.5}{258.68} = .7878$$

2. $$CF(\text{truck loading}) = \sum_{i=1}^{2} \frac{W_i \times CV_i \times PT}{LT_i}$$

$$= \frac{.2122 \times 20 \times 20}{.583} + \frac{.7878 \times 50 \times 20}{2.5}$$

$$= 145.59 \qquad + 315.12$$

$$= 460.71 \text{ Trucks per Day (TPD)}$$

3.

Activity	Truck Capacity	Total Requirement in TPD	Loading Time	Prod. Time	Capability
Loading flatbeds	20	94.17	.583	20	145.59
Loading semi-trailer vans	50	81.51	1.5 - 2.5*	20	315.12
Total	-	175.68	-	20	460.71

*NOTE: 2.5 hours was used for this analysis.

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Vita

Capt Nancy L. Needham was born on December 1, 1953 in Burlington, Iowa. She enlisted in the United States Air Force in December 1977 as an air cargo specialist and was commissioned in May 1981 as a transportation officer. Capt Needham was assigned to Headquarters Military Airlift Command as the Transportation Human Resources Officer and as Assistant Executive Officer to the Deputy Chief of Staff for Air Transportation. In 1984, she was assigned as Air Terminal Operations Center Duty Officer and Executive Officer to the Deputy Wing Commander for Air Transportation. Capt Needham is a graduate of the University of Nebraska at Omaha. She entered the School of Systems and Logistics, Air Force Institute of Technology in 1986. Upon graduation, she will be assigned to Headquarters Air Force Reserve at Robins AFB, Georgia.

Permanent address: RR 1
Danville, Iowa 52623

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Block 19. Abstract

Currently, no quantitative tool exists which would provide a complete assessment of an Air Force base's ability to interface with the Defense Transportation System. This thesis expands an Army surface transportation capability model as the basis for measuring the air transportation capability of Air Force bases. The objective for development of the new capability evaluation tool was to quantify a base's ability to receive cargo on its flight line and to move the cargo through processing facilities and off the base at various peacetime and wartime activity levels.

The assessment technique was applied to a peak work load scenario and revealed forklift and storage shortfalls, as well as, excess capability in truck loading positions. This analysis demonstrated that the Army's methodology can model all components of the transportation system and assess the capability of an Air Force base to meet mission requirements within the limits of available equipment and facilities.

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